MULTIMEDIA UNIVERSITY

STUDENT ID NO

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# MULTIMEDIA UNIVERSITY

# FINAL EXAMINATION

**TRIMESTER 3, 2015/2016**

## EPM2036 – CONTROL THEORY
( TE / RE / BE )

30 MAY 2016
2.30 p.m. - 4.30 p.m.
( 2 Hours )

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**INSTRUCTIONS TO STUDENTS**

1. This Question paper consists of 5 pages with 4 Questions only.
2. Attempt **ALL FOUR** questions. All questions carry equal marks and the distribution of the marks for each question is given .
3. Please write all your answers in the Answer Booklet provided.

**Question 1**

(a) Describe, with the help of a block diagram, the control mechanism of a driver driving a car. Explain each of the elements derived in the block diagram.

[7 marks]

(b) Consider the following transfer function:

$$F(s) = \frac{10}{s^3 + 6s^2 + 11s + 6}$$

(i) Perform the inverse Laplace Transform on $F(s)$ to obtain the time domain transfer function $f(t)$.

[6 marks]

(ii) Calculate $f(t)$ at $t = 0.5$ and $t = 1$.

[2 marks]

(c) Consider the following block diagram:

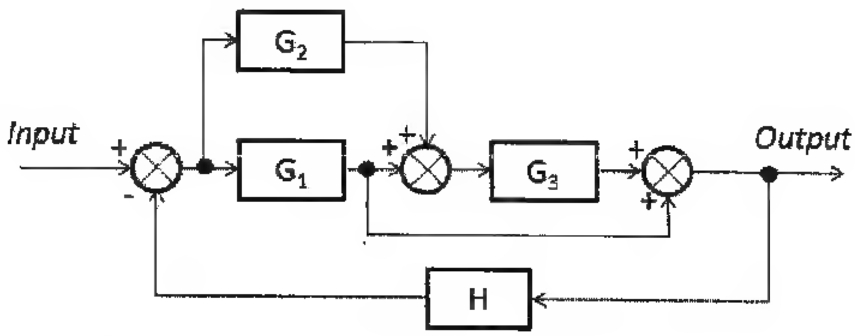


**Figure Q1.1 A Typical System's Block Diagram**

Reduce the system's block diagram into a single transfer function.

[10 marks]

**Continued...**

**Question 2**

(a) Consider the following Signal-Flow-Graph (SFG):

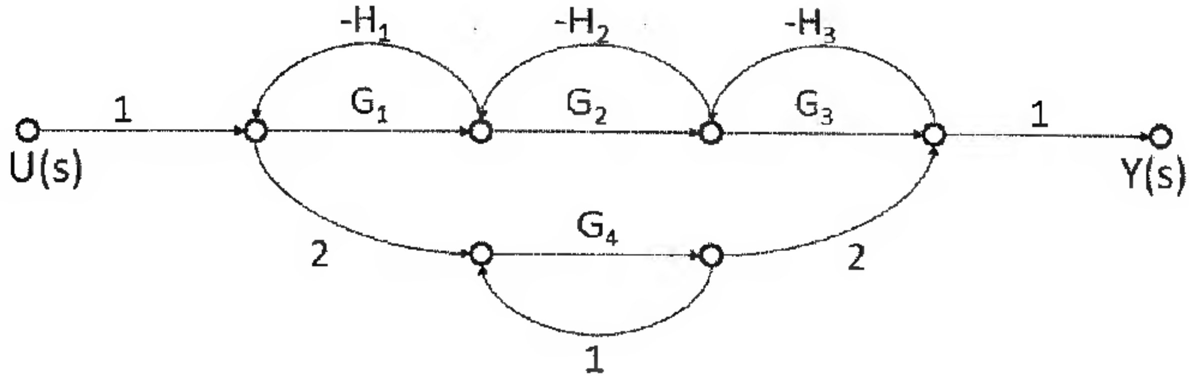


**Figure Q2.1 The Signal-Flow-Graph of a Control System**

Obtain the transfer function $\frac{Y(s)}{U(s)}$ using Mason's Rule. Write down all necessary steps in deriving the transfer function.

[15 marks]

(b) Compare the performance between an ***Underdamped System*** and an ***Overdamped System*** from the following criteria:

(i) Rise Time
(ii) Overshoot
(iii) Steady-State Error

[6 marks]

(c) Consider the following characteristic equation:

$$s^4 + 5s^3 + (k+8)s^2 + 8s + 12k = 0$$

Determine the system's stability with respect to the value of $k$.

[4 marks]

**Continued...**

## Question 3

(a) Consider the transfer function $KG(s) = \dfrac{K}{s(s+5)(s+20)}$;

(i) Draw the ***Bode Plot*** on the semilog graph if $K = 100$.

[8 marks]

(ii) If $K$ decreases to 50, is the ***Gain Margin*** of the system increased or decreased? Explain.

[2 marks]

(b) Consider a negative unity feedback control system with the following forward path transfer function

$$G(s) = \frac{50}{s(s^2 + 8s + 15)}$$

(i) Sketch the complete Nyquist plot of $G(s)$. Determine the intercepts with the negative real axis, if any.

[12 marks]

(ii) Determine the stability of the system based on the Nyquist Stability criterion.

[3 marks]

**Continued...**

## Question 4

Consider a unity feedback system with the following open-loop transfer function,

$$KG(s)H(s) = \frac{K(s+8)(s+10)}{(s+1)(s+3)}$$

where the system gain $K > 0$.

(a) Applying the root locus method, sketch the trajectories of the closed-loop roots as $K$ is varied from zero to infinity. In the root locus plot, indicate clearly the following:

(i) Starting and ending points of all branches,

(ii) Number of branches,

(iii) Angles and centroids of asymptotes, if any, and

(iv) Root loci on the real axis.

You are <u>NOT</u> required to evaluate the breakaway/break-in points or imaginary axis intercepts, if any.

[9 marks]

(b) Based on the root locus plot obtained in part (a), justify graphically if the response of the above system could achieve settling time of 1 second with an appropriate choice of gain $K$. Assume that settling time is approximated as $T_s = \dfrac{4}{\xi\omega_n}$. [2 mark]

(c) Let $K = 1$, design a suitable compensator which is to be placed in series with the above system so that the closed-loop system would achieve

(i) settling time of 1 second, and

(ii) damping ratio of $\xi = 1/\sqrt{2}$.

The transfer function of the compensator is $G_c(s) = \dfrac{K_c(s+z)}{(s+p)}$, where $K_c$ is the compensator gain, and $z$ and $p$ are the suitable zero and pole, respectively. Place the compensator zero at $s = -4$, and determine the remaining design parameters.

<u>Hint:</u> The design points are found at $s_{1,2} = -\xi\omega_n \pm j\omega_n\sqrt{1-\xi^2}$.

[14 marks]

**Continued...**

## Appendix

| $f(t)$ | $F(s)$ |
|---|---|
| Unit impulse $\delta(t)$ | 1 |
| Unit step $u_s(t)$ | $\frac{1}{s}$ |
| $t$ | $\frac{1}{s^2}$ |
| $\frac{t^{n-1}}{(n-1)!} \quad (n = 1, 2, 3, \ldots)$ | $\frac{1}{s^n}$ |
| $t^n \ (n = 1, 2, 3, \ldots)$ | $\frac{n!}{s^{n+1}}$ |
| $e^{-at}$ | $\frac{1}{s+a}$ |
| $te^{-at}$ | $\frac{1}{(s+a)^2}$ |
| $\frac{t^{n-1}}{(n-1)!}e^{-at} \quad (n = 1, 2, 3, \ldots)$ | $\frac{1}{(s+a)^n}$ |
| $t^n e^{-at} \ (n = 1, 2, 3, \ldots)$ | $\frac{n!}{(s+a)^{n+1}}$ |
| $\sin \omega t$ | $\frac{\omega}{s^2+\omega^2}$ |
| $\cos \omega t$ | $\frac{s}{s^2+\omega^2}$ |
| $\sinh \omega t$ | $\frac{\omega}{s^2-\omega^2}$ |
| $\cosh \omega t$ | $\frac{s}{s^2-\omega^2}$ |
| $\frac{1}{a}(1-e^{-at})$ | $\frac{1}{s(s+a)}$ |
| $\frac{1}{b-a}(e^{-at}-e^{-bt})$ | $\frac{1}{(s+a)(s+b)}$ |
| $\frac{1}{b-a}(be^{-bt}-ae^{-at})$ | $\frac{s}{(s+a)(s+b)}$ |
| $\frac{1}{ab}\left[1+\frac{1}{a-b}(be^{-at}-ae^{-bt})\right]$ | $\frac{1}{s(s+a)(s+b)}$ |
| $\frac{1}{a^2}(1-e^{-at}-ate^{-at})$ | $\frac{1}{s(s+a)^2}$ |

**End of paper**